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METHODS FOR USING RESONANT ACOUSTIC AND/OR RESONANT ACOUSTO-EM ENERGY TO DETECT AND/OR EFFECT STRUCTURES

TECHNICAL FIELD

The present invention relates to detection of inorganic and biologic structures and/or disruption and/or augmentation of functions of structures using acoustic, resonant acoustic, and/or resonant acousto-EM energy and/or electromagnetic properties and/or fields.

BACKGROUND OF THE INVENTION

The resonant acoustic frequency of a system is the natural free oscillation frequency of the system. A resonant acoustic system can be excited by a weak mechanical or acoustic driving force in a narrow band of frequencies, close or equal to the resonant frequency thereby inducing acoustic resonance in a targeted structure.

Acoustic resonance has been used to determine various properties of solid materials. For instance, Migliori et al in U.S. Patent Nos. 4,976,148 and 5,062,296 and 5,355,731 disclose a method for characterizing a unique resonant frequency spectroscopic signature for objects derived from ultrasonic excitation of objects, the use of resonant ultrasound spectroscopy for grading production quantities of spherical objects such as roller balls for bearings, and the use of resonant ultrasound spectroscopy with a rectangular parallelpiped sample of a high dissipation material to enable low amplitude resonance to be detected for use in calculating the elastic constants of the high dissipation sample. However, the Migliori patents are directed to solid materials and not to selectively targeting organic or biologic material especially when liquid systems are involved.

In addition to interacting with inanimate structures, acoustic energy also interacts with living, biologic organisms and structures. Acoustic energy has been used extensively in medicine and biology for imaging structures, by directing an acoustic wave at a biologic structure and analyzing the reflection pattern of the acoustic wave. Also, acoustic energy has been used in physical therapy medicine for delivering heat to targeted areas of injury or pain. However, all of the above applications depend on using acoustic energy that is non-selective

physical structure vibrates and the vibrational energy of motion may be transferred to the surrounding medium which includes air, liquid, or solid.

"Detect" as used herein is defined as determining the presence or absence of a structure, and if present identifying the structure.

"Electromagnetic (EM) properties and/or fields" as used herein includes direct and alternating currents, electric and magnetic fields, electromagnetic radiation, and fields which include but are not limited to waves, current, flux, resistance, potential, radiation or any physical phenomena including those obtainable or derivable from the Maxwell equations, incorporated by reference herein.

"Electromagnetic (EM) energy pattern" as used herein represents the electromagnetic energy produced by a structure as acoustic energy interacts with the structure and is manifested as electromagnetic properties and/or fields.

"Biologic structure" as used herein, and used interchangeably with organic, includes anything from the smallest organic or biochemical ion or molecule, to cells, organs, and entire organisms.

"Disruption" as used herein refers to deleterious effects on a structure.

"Acoustic signature" as used herein means a unique acoustic pattern that is produced by the structure when in acoustic resonance that may take the form of amplitude of signal.

"Resonant acoustic frequency" as used herein includes frequencies near or at the natural resonant frequency of the structure including harmonic and subharmonic frequencies of the natural resonant frequency to induce acoustic resonance therein.

"Acousto-EM signature" as used herein is defined as an EM energy pattern of an object in acoustic resonance and/or an EM energy equivalent in frequency to the resonant acoustic frequency.

"Acousto-EM spectroscopy" as used herein is defined as detecting a unique EM signature for a structure that is in acoustic resonance, or detecting a unique acoustic signature from a structure that is in resonance due to the introduction of electromagnetic energy, both of which can be used to detect and/or identify the structure in resonance.

"Living transducer" as used herein is defined as a biologic structure, such as a piezoelectric or semiconductor that converts electromagnetic energy or fields into mechanical

energy and/or mechanical energy into electromagnetic energy or fields.

"Cavitation" as described herein is defined as the formation of vapor-filled cavities in liquids, e.g., bubble formation in water when brought to a boil.

"Mechanical" as described herein include mechanisms such as compression and rarefaction which are thought to take place in the intensity/duration threshold region between the thermal and cavitation regions.

"Non-resonant electromagnetic signature" as used herein is defined as an EM energy pattern produced by an object stimulated by a non-resonant acoustic field.

"Resonant acousto-EM energy" as described herein means electromagnetic properties and/or fields that induce acoustic resonance in a structure.

The present invention addresses the shortcomings of the prior art by inducing acoustic resonance in a targeted structure with select frequencies that affect the specific targeted structure but have virtually no effect on nearby, non-resonating structures. Furthermore, acoustic energy power intensities can be reduced by introducing a source of electromagnetic (EM) energy that augments, or replaces, the acoustic energy thereby reducing the destructive nature of high power acoustic energy. The interaction between EM energy and acoustic resonance allows for precise detection of a structure in acoustic resonance by producing a signature with high signal to noise ratio, while producing little effect in other structures.

The present invention provides methods to selectively detect, identify and/or affect an inorganic or biologic structure by using resonant acoustic and/or acousto-EM energy which can transfer useful energy to targeted structures while leaving nearby structures, which are not in resonance, virtually unchanged.

Therefore, it is an object of the present invention to provide a method of identifying or detecting an inorganic or biologic structure using its resonant acoustic and/or acousto-EM signature and/or EM energy patterns.

It is an object of the present invention to provide a method for using resonant acoustic and/or acousto-EM signatures and/or energy patterns to augment and/or disrupt the growth and/or function of biologic structures.

It is another object of the invention to provide a method for determining resonant frequencies of a biologic structure.

It is also an object of the invention to provide a method using resonant acoustic

and/or resonant acousto-EM energies to detect the presence of and/or identify biologic structures.

In accordance with the aforesaid objects the present invention provides for the detection of inorganic or biologic structures and/or disruption and/or augmentation of growth and/or functions of said structures using resonant acoustic and/or resonant acousto-EM signatures and/or EM energy patterns.

Applying principles of acoustic resonance, the resonant acoustic frequency of a biologic system is the natural free oscillation frequency of the system, and thus a can be excited by a weak mechanical or acoustic driving force in a narrow band of frequencies. Also, depending on the size, shape, and composition of the biologic structure, there can be more than one naturally occuring resonant acoustic frequency, as well as numerous subharmonic and superharmonic resonant acoustic frequencies.

When a structure, including both inorganic and biologic structures, goes into acoustic resonance, energy builds up in it rapidly. The energy is either kept in the system or released to the surrounding environment. Energy kept in the structure can enhance the structure's functions or cause disruption of the structure. The energy in a resonant system is either intrinsically dissipated as electromagnetic energy and/or is transmitted as acoustic energy to the nearby medium. The intrinsically dissipated energy is of particular interest, because it is dissipated through molecular and atomic vibrations, producing EM energy patterns. This EM energy is referred to as acousto-EM energy because it is produced when a structure is excited by acoustic energy and some acoustic energy interacts with the structure and is converted into electromagnetic energy thereby being intrinsically dissipated. The properties, fields and/or frequencies of EM energy produced depend on the unique molecular and atomic components of the structure in question. Moreover, the induction of acoustic resonance in a structure leads to the production of a unique acousto-EM signature for that structure, which can be used to detect and/or identify the structure as disclosed in the present invention. Conversely, if a structure is targeted with an applied EM energy equivalent to its acousto-EM signature, the energy dissipation pathway is reversed, and a state of acoustic resonance can be induced. Reversing the energy dissipation pathway with an applied acousto-EM signature can be used to produce the same augmentation, detection, and disruption effects that the original resonant acoustic energy field produces. An applied acousto-EM signature can be used either by itself, or in

combination with resonant acoustic energy. Using the applied resonant acousto-EM signature and resonant acoustic energy together, allows for the use of lower power levels of both types of energy, lessening the potential adverse affects of electromagnetic energy and/or acoustic energy on nearby or adjacent nontargeted structures.

Electromagnetic energy may also interact with and complement an acoustic energy wave in a system in at least four ways: via the piezoelectric effect, intrinsic dissipation of electromagnetic energy and via the acoustoelectric or magnetoacoustic effect.

In the piezoelectric effect, acoustic vibratory energy is converted interchangeably with EM energy by a transducer. Biologic piezoelectric structures can modulate the same conversion of energy, thereby acting as living transducers. Thus, when an EM field is applied to a biologic piezoelectric structure, an acoustic wave is produced. Likewise, when an acoustic wave is applied to a biologic piezoelectric structure, EM energy is produced. The piezoelectric effect in biologic structures has many useful applications (see below.) This effect becomes even more useful when principles of acoustic resonance are applied. In the present invention specific biologic structures can be targeted with an acoustic wave or EM energy at power levels that dramatically affect the target structure, but have virtually no effect on adjacent, nonresonant structures. Although not previously postulated by others, biologic structures functioning as living, resonant piezoelectric transducers which modulate the conversion of mechanical and EM energy is undoubtedly one of the major underlying mechanisms responsible for the interaction of EM fields with biologic structures.

In the acoustoelectric effect, the passage of an acoustic wave through a semiconductor induces an electric current. The passage of an acoustic wave through the material is postulated to cause a periodic spatial variation of the potential energy of the charge carriers. This results in an electric field across the ends of the semiconductor as long as the acoustic wave is traversing the semiconductor. Free electron carriers are bunched in the potential-energy troughs, and as the acoustic wave having a specific frequency propagates, it drags the bunches along with it, resulting in an electric field such as a DC field pulsing at the specific acoustic frequency or an AC field having a frequency equal to the specific acoustic frequency. The effect is enhanced where there are both positively and negatively charged carriers, and where there are many different groups of carriers - conditions which are frequently found in biologic systems. The attributes of the current

produced depend on the unique molecular and atomic components of the structure in question. This aspect alone provides a means to perform acoustoelectric spectroscopy on biologics many of which are semiconductors, and depending on the selected frequency, the acoustoelectric effect in biological structures has many other potentially useful applications. Thus understood, a targeted structure can be irradiated or exposed to acoustic energy having non-resonant frequency and an electromagnetic energy pattern of the acoustoelectric effect in the structure can be detected. This detected non-resonant electromagnetic signature can be used as a signature to affect, detect and identify the targeted structure.

However, the acoustoelectric effect becomes even more useful when principles of acoustic resonance are applied. Augmentation, detection, and/or disruption of biologics can be targeted to specific structures at power levels that dramatically affect the target structure, but have virtually no effect on nearby, nonresonant structures. The current produced by the acoustoelectric effect in a resonant structure will be much stronger than any current produced by neighboring non-resonant structures, and may be of an alternating nature. The large signal to noise ratio obtained from a resonant structure improves accuracy of acoustic and EM energy pattern identification and detection. Similar to reversal of the piezoelectric effect and acoustic resonance intrinsic energy dissipation pathway (see above), application of the resonant acoustoelectric EM energy pattern to a targeted structure will amplify the acoustic wave (acoustoelectric gain which peaks at the frequency for which the acoustic wavelength is the Debye length, where bunching is optimum). Thus, combined use of the resonant acoustic, acoustoelectric and/or EM fields permit greater tissue penetration of high frequency acoustic energy that would otherwise be highly attenuated and have poor tissue penetration. Using the resonant acoustic frequency, acoustoelectric and/or EM fields together also allows for the use of lower power levels of these types of energy, lessening the potential effects on other nontargeted and nonresonant structures.

The magnetoacoustic effect is the magnetic-field-dependent attenuation of an acoustic field in a monotonic, oscillatory, or resonant manner, depending on the electronic properties of the substance in question. This variability in result, depending on structural composition, provides a further enhancement of acousto-EM spectroscopy in relation to biologics and other structures, via addition of a magnetic field. Also, the addition of a magnetic field provides the means to amplify or attenuate an acoustic field, thus improving or modulating

the penetration of the acoustic field in biologic tissues.

Similarly, resonant acoustics combined with acoustic cyclotron resonance (ie. resonant acoustic cyclotron resonance) and Doppler-shifted resonant acoustic cyclotron resonance presents a powerful, and precise means of selectively causing augmentation, detection and/or disruption of structures.

The present invention provides a method that applies the principles of acoustic resonance to biologic structures for the purpose of disruption and/or augmentation of functions of the specifically targeted biologic structure. The resonant acoustic frequency of a biologic structure may be determined by performing resonant acoustic spectroscopy using methods and systems well know in the art. Particularly, a resonant acoustic frequency of a biologic structure may by determined by the steps of:

a) applying acoustic energy to the biologic structure and scanning through a range of acoustic energy frequencies; and

b) detecting at least one specific frequency which causes a maximum signal output from the biologic structure indicating the biologic structure being induced into acoustic resonance by the at least one specific frequency.

The specific frequencies causing the maximum signals are the resonant acoustic frequencies of the biologic structure which are defined and used herein as the acoustic signature of the biologic structure. Once determined, at least one resonant acoustic frequency may be applied to the biologic structure to affect functioning therein and/or to determine its acousto-EM signature.

The acoustic energy, including the resonant acoustic frequencies (i.e., the acousto-EM signature) may be applied at a power level sufficient to affect functioning of the biologic structure. Depending on the power intensity of the acoustic energy, and the type of targeted structure that is induced into acoustic resonance, the structure may have its functions affected, such as disruption and/or augmentation.

At lower power levels functions of the biologic structure can be augmented while at higher power levels disruption of the structure may occur. Augmentation as used herein encompasses beneficial effects on the biologic structure. Such augmenting of functions or enhancing effects include but are not limited to enhancement of growth, reproduction, regeneration, embryogenesis, metabolism, fermentation, and the like. The results of such

enhancement include but are not limited to increase in bone mass or density, increase in number and maturation of eggs, increase in number and/or function of leukocytes, increase in fermentation products in beer, wine and cheese manufacturing, increase in plant germination and growth and the like.

There are some situations where the ability to selectively disrupt a structure with acoustic resonance is very useful as disclosed in the present invention. As stated above, disruption as used herein refers to deleterious effects on the biologic structure. Such deleterious effects include but are not limited to structural failure of the biologic structure resulting in lysis, shattering, rupture or inactivation of the biologic or of one or more components of the biologic structure. Disruption as used herein also includes within its ambit inhibition of vital processes required for growth, reproduction, metabolism, infectivity and the like. Components which may be targeted for disruption include, but are not limited to DNA, RNA, proteins, carbohydrates, lipids, lipopolysaccharides, glycolipids, glycoproteins, proteoglycans, chloroplasts, mitochondria, endoplasmic reticulum, cells, organs and the like. In the case of virulent organisms, the virulence factors may be specifically targeted for disruption to prevent or inhibit the growth, infectivity or virulence of the organism. Such virulence factors include but are not limited to endotoxins, exotoxins, pili, flagella, proteases, ligands for host cell receptors, capsules, cell walls, spores, chitin, and the like.

Organics, biologics or one or more targeted portions thereof which are amenable to disruption using the methods of the present invention include but are not limited to viruses, bacteria, protozoans, parasites, fungi, worms, mollusks, arthropods, tissue masses, and the like. The organics or biologics to be disrupted may be isolated, present in a multicellular organism or portion thereof, or other complex environment.

It is postulated that disruption of the targeted biologic structure without affecting nearby tissue or structures occurs due to acoustic resonance being induced only in the targeted structure which until now has not been considered a mechanism to affect a biologic structure. This is very different from that disclosed in the prior art which contemplates only three mechanisms for affecting a biologic structure which include cavitation, thermal and mechanical.

At specific power levels, such as in lower levels, that do not cause the actual disruption of a structure, resonant acoustic energy can intrinsically dissipate within the

structure. This intrinsically dissipated acoustic energy can be converted by the structure into an electromagnetic energy having specific properties and/or fields that may be manifested as direct and alternating currents, electric and magnetic fields, electromagnetic radiation and the like. The pattern of the electromagnetic energy represents a produced acousto-EM signature of the structure.

The present invention provides a method to determine an acousto-EM signature of a structure which comprises irradiating the structure with acoustic energy having a frequency at or near a previously determined resonant acoustic frequency of the structure to induce resonance therein and detecting the electromagnetic energy pattern caused by the intrinsic dissipation of energy.

Once an acousto-EM signature is determined for a specific structure, this structure can be induced into acoustic resonance by applying an EM energy pattern or equivalent to the acousto-EM signature of the structure. Typical electromagnetic energies applied include direct and alternating current, electric and magnetic fields, and electromagnetic radiation and the like.

As such, the present invention applies the principles of acoustic resonance by applying resonant acoustic frequencies and electromagnetic energy equivalent to the predetermined acousto-EM signature of a targeted structure individually, or in combination, to affect the targeted structure, the method comprising the steps of :

a) applying at least one resonant acoustic frequency of the targeted structure; and/or

b) applying electromagnetic energy equivalent to part or all of the acousto-EM signature of the targeted structure; and

c) applying (a) and/or (b) each at a power intensity level to induce acoustic resonance within the targeted structure and affect functioning of the structure.

Either the resonant acoustic frequency of the targeted structure or the acousto-EM signature must be predetermined, as discussed above, to provide the applicable energy for inducing acoustic resonance in the structure. The electromagnetic energy can be introduced into the targeted structure in the form of a direct or alternating current having a specific frequency that is equivalent to the electromagnetic energy pattern (i.e., the acousto-EM signature) detected when the structure is induced into acoustic resonance. Furthermore each type of energy can be applied at a power level less than used individually and this allows for inducing acoustic resonance

in the structure with the possibility of reducing damage to the structure.

The present invention provides a method for detecting and/or identifying inorganic or biologic structures using resonant acoustic and/or acousto-EM energy. The method includes determining the acoustic signature of a structure by irradiating the structure with a range of frequencies to determine the specific frequency and/or frequencies that induce acoustic resonance therein to provide an acoustic signature of the structure. The acoustic signature can be compared with reference signatures to detect and/or identify the structure.

Furthermore, the identification and/or detection of a structure can also be achieved by detecting an acousto-EM signature of a targeted structure, the method comprising the steps of:

a) inducing acoustic resonance in the targeted structure; and

b) detecting an electromagnetic energy pattern from the targeted structure in acoustic resonance which represents an acousto-EM signature of the structure.

The acousto-EM signature can be compared to reference signatures to detect and/or identify the structure.

The targeted structure can be induced into acoustic resonance by introducing acoustic energy including at least one resonant acoustic frequency, electromagnetic energy equivalent to the resonant acoustic frequency, and/or an electromagnetic energy pattern equivalent to the acousto-EM signature.

The electromagnetic energy pattern manifested as electromagnetic properties and fields may be determined by detection means well known to those skilled in the art such as those disclosed in *Introduction to Electromagnetic Fields and Waves*, by Erik V. Bohn Addison-Wesley Publishing Co., 1968, the contents of which are incorporated by reference herein.

In another embodiment of the present invention, a structure may be induced into acoustic resonance by applying to the structure part or all of the acousto-EM signature of the structure to induce the structure into acoustic resonance. If the structure is induced into acoustic resonance, this fact may be used to detect and/or identify the structure. This represents another method of the present invention that may used for identification or detection of a specific structure, because each structure will not only have its own unique acoustic signature but also will have a unique acousto-EM signature to which it responds by

resonating acoustically. Also, depending on the power intensity of the electromagnetic properties and/or fields and the type of targeted structure that is induced into acoustic resonance, the structure may have its functions affected, such as disruption and/or augmentation.

In all the above embodiments the introduction of acoustic and/or electromagnetic energy including a resonant acoustic frequency can be applied in either continuous and/or periodic form depending on the desired effect.

The acoustic and/or EM energy or fields may be applied individually or in combination. Likewise the acoustic and/or EM energy or fields may be detected individually or in combination.

Many biochemical compounds and biologic structures are naturally occurring crystals and especially susceptible in that regard to the effects of resonant acoustic energy. Many biologic substances are piezoelectric materials. For instance, bone is a piezoelectric material and the piezoelectric properties of bone play a vital role in its biological functions. As such, it is further envisioned by the inventors that biologic structures having a piezoelectric nature may be affected by applying a sufficient amount of acoustic energy and/or electromagnetic energy to induce the structure into resonance thereby affecting the functions of the biologic structure either positively or negatively. Thus understood, biologic structures that act as living transducers may be induced into acoustic resonance by introducing electromagnetic energy equivalent to a resonant acoustic frequency of the biologic structure which is converted to mechanical energy by the living transducer thereby inducing acoustic resonance in the structure.

Another aspect of the invention is a system for detecting a biologic or inorganic structure by determining the resonant acoustic and/or acousto-EM signature of the structure comprising:

a) means for inducing acoustic resonance in the biologic or inorganic structure;

b) means for detecting the acoustic signature of the biologic or inorganic structure; and

c) means for comparing the acoustic signature of the biologic or inorganic structure with a reference acoustic signature of the structure.

Also, the above system may also or instead comprise means for detecting a resonant acousto-EM energy signature of the structure in acoustic resonance which produces an

electromagnetic energy pattern such as described above. The acousto-EM signature can be compared with a previously determined reference acousto-EM signature by providing means for comparing in a detection or identification system. The electromagnetic energy pattern is manifested as electromagnetic properties and/or fields that include but are not limited to energy in the form of direct and alternating current, electric and magnetic fields, and electromagnetic radiation. The targeted structure can be induced into acoustic resonance by introducing acoustic energy including at least one resonant acoustic frequency, electromagnetic energy equivalent to the resonant acoustic frequency, and/or an electromagnetic energy pattern equivalent to the acousto-EM signature.

In another embodiment of the present invention a system for augmenting and/or disrupting a targeted biologic structure comprises means for applying acoustic energy including a previously determined resonant acoustic frequency to induce acoustic resonance in the biologic structure, the acoustic energy being applied at a sufficient power input to affect functions of the biologic structure. Alternatively, the targeted structure may be induced into acoustic resonance by providing electromagnetic energy equivalent to the resonant acoustic frequency or the acousto-EM signature that was previously determined, such electromagnetic energy including direct and alternating current, electric and magnetic fields, and electromagnetic energy.

In yet another embodiment a system is provided to introduce acoustic energies having acoustic frequencies at or near the resonant acoustic frequencies of the targeted structure and also electromagnetic energy to augment the resonant acoustic frequencies comprising:

means for introducing a frequency at or near the resonant acoustic frequency of the targeted structure ; and

means for introducing electromagnetic energy equivalent to the electromagnetic energy pattern previously determined as an acousto-EM signature of the structure, such means including direct and alternating current, electric and magnetic fields, and/or electromagnetic radiation and the like.

The acoustic energy and EM energy equivalent to the acousto-EM signature may be applied and/or detected by a single means that can apply both types of energy.

Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in

EM energy ← piezoelectric transducer ← acoustic energy waves.

Thus, piezoelectric transducers may be used to both produce and detect acoustic energy, using the reversible piezoelectric effect.

The structure after being induced into an acoustic resonance state will emit vibrational waves that will cause mechanical stress in the transducer. In turn, an alternating potential difference having the same frequency as the acoustic wave appears as voltage across electrodes connected to a transducer. This voltage is converted via oscilloscope type devices to a readable format.

Oscilloscopes that may be utilized in the present invention include but are not limited to those such as the BK Precision 21 60A (0-60 MHz), the Tektronix TDS 784A (0-1 GHz), the Tektronix TDS 820 (6-8 GHz), the Tektronix 1180 a B (0-50 GHz); and spectrum analyzers such as Hewlett-Packard 8577A (100 Hz-40 GHz), HP 8555A (10 MHz -40 GHz), Tektronix 492 (50 KHZ-21 GHz), Anritsu MS62C (50 Hz-1.7GHz), and Polarad 640B (3 MHz-40 GHz) which are all commercially available.

Complete acoustic detection and analysis systems (50 KHz-100 MHz) including power frame, computer interface, pulse width generator, gated amplifier, broadband receiver, phase detector, control software, pre-amplifiers, diode expander, diplexer, filter, and attenuators can be purchased commercially from Matec Instruments Inc., or from other sources.

The acoustic energy under examination can be either reflected or transmitted. For example, in traditional medical ultrasound methods, an acoustic wave is produced from a single transducer. The acoustic wave strikes various structures. Some of the acoustic wave is reflected back from the structures and is detected as reflected waves by the same single transducer. Some of the acoustic wave may also be transmitted through the structures. Many industrial applications of acoustic energy utilize the transmitted, rather than reflected waves.

The present invention also comprises delivering EM energy at resonant acoustic and/or resonant acousto-EM frequencies to a targeted structure as shown in Figures 3- 7.

If a resonant system is embedded in a fluid environment (as is the case with most biologic structures) the dissipation of energy occurs through an intrinsic source in the system (i.e. via conversion to EM energy), or through loss to the nearby medium (via coupling and

identical proteins.

In some viruses, a lipoprotein membrane, or envelope, surrounds the capsid. The envelope is derived from host cell membranes and is modified by the virus during its departure from the host cell. The envelope may carry specific virus proteins such as hemagglutinin or neuraminidase that are important for future functions and survival of the virus. The envelope of some viruses is studded with projections, or peplomers, which look like a fringe around the edge. The fringe may also be important for function and survival of the virus.

Classically, the piezoelectric phenomenon is said to exist when the application of a mechanical stress to certain dielectric (electrically nonconducting) crystals produces electric polarization (electric dipole moment per cubic meter) which is proportional to the mechanical stress. Conversely, application of an EM field to a crystal produces mechanical stress and distortion, and hence acoustic energy.

A necessary condition for the piezoelectric phenomenon in a crystal is the absence of a center of symmetry. Twenty of the 32 classically defined crystal classes lack a center of symmetry and are piezoelectric. Viruses are crystalline structures and as such are susceptible to vibrational effects by the use of resonant acoustic and/or acousto-EM energy. Icosahedral viruses have 5-fold symmetry and thus do not have a classical center of symmetry in their crystalline structure, the necessary condition for a piezoelectric substance. Helical viruses likewise do not have a classical center of symmetry, as the spiraling capsids are offset from the 90 degree horizontal of the center axis. In addition to the crystalline structure of viruses being susceptible to the vibrational resonant effects of acoustic energy, viruses, as used in the present invention, may also function as piezoelectric, acoustic resonance structures.

The classical 32 groups of naturally occurring crystals defined in non-organic chemistry, do not include a group with 5-fold or offset helical symmetry. It is postulated by the inventors that viruses may represent a 33rd and 34th group of naturally occurring crystals.

The present invention has the potential to significantly reduce the number and severity of viral infections suffered by the world population. The invention has the potential to augment production of vaccines, or viral gene transfer. Also, the present has veterinary

In another embodiment, receiving acoustic transducer mode also detects qualitative and quantitative resonant acoustic frequencies of the virus in the multicellular organism to determine efficacy and duration of treatment.

The present invention also provides a means to determine qualitative and quantitative resonant acoustic and/or acousto-EM frequencies *in vitro* as shown in Figure **19 A&B**. A test device, as described above and shown in Figure **12**, with any and all embodiments, is fitted with transmitters and receivers to transmit, detect, measure, and analyze EM energy. When the resonant acoustic frequencies are applied to the virus test disk, a unique electromagnetic energy pattern is generated, according to the structure and composition of the virus and test disk under study, referred to herein as the resonant acousto-EM signature. Mechanisms producing the resonant acousto-EM signature include, but are not limited to piezoelectricity, acoustoelectricity, magnetoacoustics, and/or intrinsic energy dissipation. The resonant acousto-EM signature represents one or more of several electromagnetic properties and/or fields including, but not limited to, direct current, alternating current, magnetic field, electric field, EM radiation, and/or acoustic cyclotron resonance (standard or Doppler shifted).

All of the above mentioned forms of EM energy are detected, measured, and analyzed with devices and methods known to those skilled in the art. (It should be noted that useful information may also be derived from application of nonresonant frequencies, ie. current characterization of semiconductor biologics via the acoustoelectric effect.) This data in combination with resonant signatures yields even greater sensitivity and specificity to the method. For example, Herpes simplex virus (HSV) I and II will have nearly identical resonant acoustic signatures because they are virtually identical in size and shape. They differ in molecular protein configuration, however, and can be distinguished by their acousto-EM signatures. This includes, but is not limited to, characterization at nonresonant and resonant frequencies of acoustoelectric currents, acousto-EM signatures produced via intrinsic energy dissipation, of acoustic modulation or attenuation in the presence of a magnetic field via the magnetoacoustic effect, and of electric or magnetic fields induced or affected by any of the above processes.

In another embodiment, the test device is also fitted with any and all combinations of resonant acoustic and acousto-EM generating equipment. A sample of unknown composition

a multicellular organism using a resonant acoustic and/or acousto-EM field probe. For example, as shown in Figure **23**, a hand-held probe is fitted with an EM radiation generating device, as currently known to those skilled in the art. A predetermined EM radiation field (frequencies, harmonics, amplitude, mode, shape, etc.) replicating the acousto- EM signature representing the intrinsic dissipation pattern of a particular virus, is delivered to a predetermined portion of the organism, from the hand-held probe. For example, in a person afflicted with an upper respiratory tract infection (a "cold"), the treatment is delivered through the skin over the nose, throat, and sinuses, reversing the intrinsic energy dissipation pathway of the rhinovirus and inducing resonant acoustic oscillations which disrupt the rhinovirus.

Example 2

Disruption, Augmentation, Detection and/or Identification of Micro-organisms

Any micro-organism, such as bacteria, as well as structure and molecules contained or associated herewith, may be augmented, disrupted, detected and/or identified *in vitro* or *in vivo* using the methods of the present invention. Bacteria include, but are not limited to, those associated with animals, man, avians, reptiles, amphibians, insects, aquatic life, plants, fruit, soil, water, oil, fermentation processes for food production, and the like. In one embodiment the bacteria include but are not limited to *Streptococcus sps., Staphylococcus sps., Hemophilus sps., Neisseria sps., Treponema sps., Salmonella sps, Shigella sps, Escherichia coli strains, Corynebacteria sps., Bordetella* sps., *Chlostridrium sps., Rickettsia sps., Chlamydia sps, Brucella sps., Mycobacterium sps.,Borrelia sps., Mycoplasma sps., Lactobacillus sps.,* strains thereof and the like. Human illnesses caused by bacteria include pneumonia, skin and wound infections, heart valve infections, gastroenteritis, syphilis, gonorrhea, the plague, urinary tract infections, lyme disease, tuberculosis, cholera, typhoid fever, anthrax, tetanus, and gangrene.

Fungal infections include athlete's foot, ringworm, vaginal yeast infections, oral thrush, histoplasmosis, and cryptococcus.

Diseases in animals caused by bacteria, fungi, protozoa and worms are similar to those in humans. Similarly, a wide range of micro-organisms infect plants, and even other micro-organisms are deemed to be beneficial (e.g., bakers yeast.).

Example 4

Augmentation of Bone Growth

Bone demineralization in humans is a significant health care problem. Thousands of elderly people sustain fractures of the hip, leg, or arm due to this bone demineralization (osteoporosis). These injuries cost the American health care system billions of dollars a year, for treatment, surgery, and rehabilitation after the injury. In addition, the overall health status of the victims is impaired, and they suffer loss of time and quality of life due to these fractures. Other conditions which contribute to bone matrix loss include weightlessness (e.g., in outer space) and prolonged confinement to bed. People in certain occupations may benefit from an increase in the normal bone density. Examples include professional athletes, military personnel, and jobs requiring exposure to increased atmospheric pressures (e.g., undersea diving).

Living bone is organized in a calcium based crystalline structure of hydroxyapatite, doped with copper, and embedded in collagen fibers. The application of force to the collagen fibers in the bony matrix, through mechanical pressure or gravitational fields, stimulates the piezoelectric effect and flow of ions via fluid channels in bone. This small electrical charge, in turn, acts as a signal to the body's osteoblasts to deposit more hydroxyapatite. As the hydroxyapatite density increases, the bone becomes stronger. Thus, bones maintain their normal structure and density in response to pressures and forces encountered in normal daily activities, via a piezoelectric effect.

With aging, normal copper doping is lost, and the piezoelectric effect diminished. The result is that hydroxyapatite density is not maintained, and the elderly suffer from osteoporosis and bone fractures. The same thing occurs in the absence of normal activity (weightlessness and confinement to bed), with subsequent absence of the normal piezoelectric effect and ionic current flows.

Bone is a crystalline piezoelectric structure and as such is subject to the vibratory effects of acoustic energy. The operative process behind normal physiologic bone density maintenance is the generation of hydroxyapatite molecular movement within collagen fibers, compressed by macro-pressures. These occur from daily activities, and stimulate the piezoelectric and subsequent bone building osteoblastic effects.

This molecular movement and the collagen fiber compression can also be generated from micro-pressures within the semiconductor matrix of bone. Thus understood, micro-pressures can be produced by acoustic energy waves.

In addition to the piezoelectric effect, since bone is a piezoelectric and semiconductor structure, it will exhibit the acoustoelectric, intrinsic dissipation and magnetoacoustic effects. Conditions with diminished bone semiconductor function (osteoporosis) and/or decreased macro-pressures(weightlessness and bed confinement) can be effectively treated through application of acoustic micro-pressures which generate a biological piezoelectric effect, and/or also via acoustic resonance, intrinsic dissipation, acoustoelectric and magnetoacoustic effects.

Prior literature describes the use of non-resonant ultrasound to speed the rate of healing of bone fractures, however, the mechanism causes gross disruption of the bone tissues, which in turn damages the microscopic capillary bed in bone, with leakage of serum and cells into the bony matrix, and with subsequent bone mineralization. The literature also describes attempts to use ultrasound to detect resonant frequencies of the structure of entire bones (femur and ulna) to diagnose a bone as normal or defective. However, the use of resonant acoustics and/or acousto-EM frequencies to activate the piezoelectric effect is not described. No consideration is given in the prior art to using bone as a living transducer for the piezoelectric, intrinsic dissipation, acoustoelectric, and magnetoacoustic effects, either alone or in combination with a resonant acoustic field.

The present invention takes advantage of the crystalline, piezoelectric structure of bone for the purpose of augmenting bone growth and calcification. The invention has the potential to significantly reduce the number and severity of bone fractures suffered by victims of osteoporosis. The invention has the potential to speed the healing process of fractures. Other conditions which contribute to bone matrix loss, such as weightlessness (i.e., in outer space), or prolonged confinement to bed, would also benefit from the invention. The invention has the potential to aid people in occupations which would benefit from an increase in their bone density (athletes, military personnel, and jobs requiring exposure to increased atmospheric pressures such as undersea diving.) The invention also has potential veterinary applications. Unlike prior treatment using ultrasound, the present invention uses resonant acoustic and/or acousto-EM frequencies of bone to stimulate at least the piezoelectric effect

endangered species could be aided through the use and detection of resonant acoustic and/or acousto-EM frequencies specific for those organisms. The use of resonant acoustic and/or acousto-EM frequencies could potentially aid in the identification and differentiation of species and subspecies throughout the animal, plant, and microbiological kingdoms.

Examples of multicellular organisms whose growth and augmentation are desired for harvesting include plants and protein sources such as fish, clams, shrimp, chickens, and other livestock. Medicines, drugs, and chemicals harvested from a wide variety of plant and animal sources include hormones, perfumes, dyes, and vitamins. Other materials harvested from plant and animal sources are such an intrinsic part of human activities that they are simply too numerous to list (i.e., pearls, clothing fibers, building materials, leather, etc.) At lower power inputs of the resonant acoustic and/or acousto-EM frequencies, these organisms and their structures can be selectively augmented.

The present invention takes advantage of the discrete shape and size of numerous organisms to make use of resonant acoustic and/or acousto-EM frequencies specific to those organisms, for purposes of augmentation, identification, detection and/or disruption. Using the piezoelectric, intrinsic energy dissipation, acoustoelectric, and/or magnetoacousto effects, the invention has the potential to produce the above results by applying an electromagnetic energy pattern of the specific acousto-EM signature, either alone or in combination with a resonant acoustic field. The present invention has the potential to provide chemical-free control of numerous pests. The present invention also has the potential to provide for the detection and identification of numerous species of organisms. Lastly, the present invention has the potential to augment growth and metabolism in and of structures in various species deemed beneficial.

The present invention provides a means to augment, detect, and/or disrupt structures of multicellular organisms using resonant acoustic and/or acousto-EM energy. For example, as shown in Figure **32,** a transducer apparatus with the resonant frequency for the cement plate of barnacles (by which they attach themselves to the hulls of ships) is fitted into an underwater "scrubber" which is operated remotely from the deck of the ship via cables, or from inside the vessel via RF control. As the scrubber moves along the outside of the hull, the acoustic wave disrupts the cement plate of the barnacles, causing them to lose their grip on the hull and fall off into the ocean.

control peas sprouted. The acousto-EM exposed peas were almost twice the length of the control peas.

DAY 6 - 45 of the peas exposed to the acousto-EM field had sprouted while only 35 of the control group had sprouted.

DAY 10 - 61 of the peas exposed to the acousto-EM field had sprouted while only 45 of the control group had sprouted. The average length of the leaf sprout on the exposed acousto-EM field group was 3.3 cm while the average length of the control group was only 2.7 cm.

RESULTS: Applying an acousto-EM signature augmented the germination and growth rate of the peas.

Example 11

Detection and Identification of Inorganic Structures

The methods and systems of the present invention have a wide range of useful applications, such as on-site identification both qualitatively and quantitatively of various types of inorganic matter or structures, recognition of impurities in metal alloys, recognition of armaments and weapons, such as plastic explosives, etc.

Detection and identification can be achieved by applying acoustic energy at a frequency closely matching the resonant frequency of an object or structure thereby inducing acoustic resonance therein for detection of a unique acoustic and/or acousto-EM signature. Using methods known to those skilled in the art, any device capable of generating and transmitting acoustic energy through any medium can be used to generate the resonant acoustic and/or acousto-EM signatures utilized by this invention including the apparatus disclosed and shown above in Figure **1**.

Using methods known to those skilled in the art, any device capable of detecting and analyzing acoustic energy and/or EM energy through any medium can be used to detect the resonant acoustic and/or acousto-EM signatures utilized by the invention such as disclosed and shown above in Figure **2**.

The system shown in Figure **12** gives a schematic overview of the necessary components to be utilized in determining resonant acoustic frequencies of different inorganic materials or structures. Predetermination of the specific frequencies and acoustic and/or